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MAINTENANCE STRATEGIES AND THEIR COMBINE IMPACT ON MANUFACTURING PERFORMANCE

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ABSTRACT

Maintenance function has become challenging in the current competitive environment. Adoption of suitable maintenance strategy for plant assets is crucial decision. This paper discussed different maintenance strategies and their impact on manufacturing performance. Each particular maintenance strategy has its own important role for enhancing manufacturing performance of industries. The aim of this study is provide an extensive journey of maintenance through keen review. This literature study suggests a hypothetical based model which link maintenance function to manufacturing performance with mediator of some factors.

KEYWORDS: Maintenance, Maintenance Strategy & Integrated Model

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Original Article

INTRODUCTION

Over recent years, the role of maintenance and therefore maintenance management has grown rapidly, within Indian manufacturing sector. Maintenance has become more challenging in the current dynamic business environment (Mad Lazim & Ramayah, 2010). Further, generation of defects not only produces waste but they can also grind the production process to a halt. There has a need to have proper maintenance strategies to monitor, manage and optimize equipment utilization and eventually maximizing throughput. Since It is necessary to choose suitable maintenance strategy to run the plant and machinery problem free (Wararkar). Thus maintenance managers have to adopt best maintenance practice from several maintenance strategies for each element of machine or system(Bevilacqua & Braglia, 2000). Many authors have reported maintenance as profit generating function(Alsyouf, 2007; A. Sharma, Yadava, & Deshmukh, 2011; Wararkar); Bevilacqua and Braglia (2000) reported about maintenance cost, which lie between 15% to 70% of total production cost(Bevilacqua & Braglia, 2000); Salonen and Deleryd (2011) highlighted rise of maintenance cost near about 30% due to bad planning, overtime and unsystematic preventive maintenance(Salonen & Deleryd, 2011). This progression triggers the interest to identify any research that has reported either individual or the combination of maintenance strategies to reduce cost and enhance manufacturing performance of plant or machinery. However, integrated maintenance practice may require as per the current need of particular industries. Maintenance as a strategic decision can be remove any potential of equipment failure, deterioration, stoppages and breakdowns(Mad Lazim & Ramayah, 2010). Hence, it is clear that design of maintenance model in such way that it must be reliable and give the optimum results. This paper has two main objectives: (1) to search all possible literature related to maintenance strategies and classify them; (2) to advocate integrated concept and suggest hypothetical model interlink maintenance function to manufacturing performance.

The organization of the paper is as follows: after a brief introduction, literature reviews is provided in Section II. Maintenance strategies classified in section III. A hypothetical integrated maintenance model is proposed in Section IV and section V pinpoints the conclusions and underline research for future.

LITERATURE REVIEW

In the literature review, the definition of the term "maintenance strategy" is either too narrow or too vague. Alsyouf (2007) defined maintenance strategy is as the set of various maintenance interventions (corrective, preventive, predictive, proactive, etc.) and the general structure in which these interventions are foreseen(Alsyouf, 2007). Furthermore, Swanson (2001) explains three types of maintenance strategies: reactive strategy i.e, corrective maintenance; proactive strategy i.e, preventive and predictive maintenance; and aggressive strategy i.e, total productive maintenance (Swanson, 2001). However, Bevilacqua and Braglia (2000) consider each maintenance policy as a separate strategy (Bevilacqua & Braglia, 2000). Furthermore**,** maintenance is a support function in businesses, plays an important role in backing up many emerging business and operation strategies like lean manufacturing, just-in-time production, total quality control and six-sigma programs(Pun, Chin, Chow, & Lau, 2002). The recent competitive trends and ever increasing business pressures have been putting maintenance function under the spotlight as never before(Garg & Deshmukh, 2006). According to a survey studied within Belgian industries out of 46 respondents, 71 per cent considered that maintenance could be used as a tool for enhancing the competitive advantage of the company(Pinjala, Pintelon, & Vereecke, 2004). Effective, maintenance strategy at any level – say at a business or functional level – will provide the company with a sense of direction, integrity and purpose(Raouf et al., 2006). In addition, it should be more proactive in contributing to the competitive advantage of a company. Maintenance strategy provides critical support for heavy and capital-intensive industries by keeping the productivity performance of plants and machineries in a reliable and safe operating condition(Parida, Kumar, Galar, & Stenström, 2015).

MAINTENANCE STRATEGIES

Mostafa (2004) explains the simplification of the maintenance strategies just as planned and unplanned maintenance(Ismail Mostafa, 2004). In addition, maintenance strategies have significantly evolved during the last 50 years progressing from breakdowns to preventive, predictive, then pro-active and synergic approach. However, review and more description of some of these maintenance concepts are summarized below Table 1. and Figure 1 shows the performance journey of maintenance strategies in different time duration. According to journey of maintenance, various researchers & academicians have classified and characterized the maintenance strategies as follows:

Table 1: Maintenance Techniques/Strategy Characteristics (Deshpande & Modak, 2002; Garg & Deshmukh, 2006; Kaur, Singh, & Singh Ahuja, 2012; Parida & Chattopadhyay, 2007; A. Sharma et al., 2011; Willmott, 1994)

Generation (Period)	Techniques	Strategy	Characteristics
First (1940s, 1950s)	Breakdown Maintenance	Breakdown	No budget constraints, Fix at Fail
Second(1960s,1970s)	Planned Preventive	Preventive	Periodic part inspection or Replacement
Third (1980s, 1990s,2000)	Condition Based Maintenance	Predictive	Health trend monitoring and prognosis
Third (1980s, 1990s,2000)	Reliability centered Maintenance	Predictive/ Pro-active	Design for Reliability and maintainability
Third (1980s, 1990s,2000)	Total Productive Maintenance	Pro-active (Holistic)	The way for Zero – Defects / Accidents/ Breakdowns.

Table 1: contd.,			
Fourth (2000, 2010s,2015)	TPM integrating with lean tools (like TQM,VSM, JIT, CI, etc.)	Synergic Approach/ Integrated Practices	The way for continuous improvement and preparing self need based model in manufacturing industries.

Unplanned Maintenance

These strategies are not accepted or desired yet exist in industries due to several reasons and one of the causes is 'improper planning' and no compliance to plans. Such activities are further classified as follows;

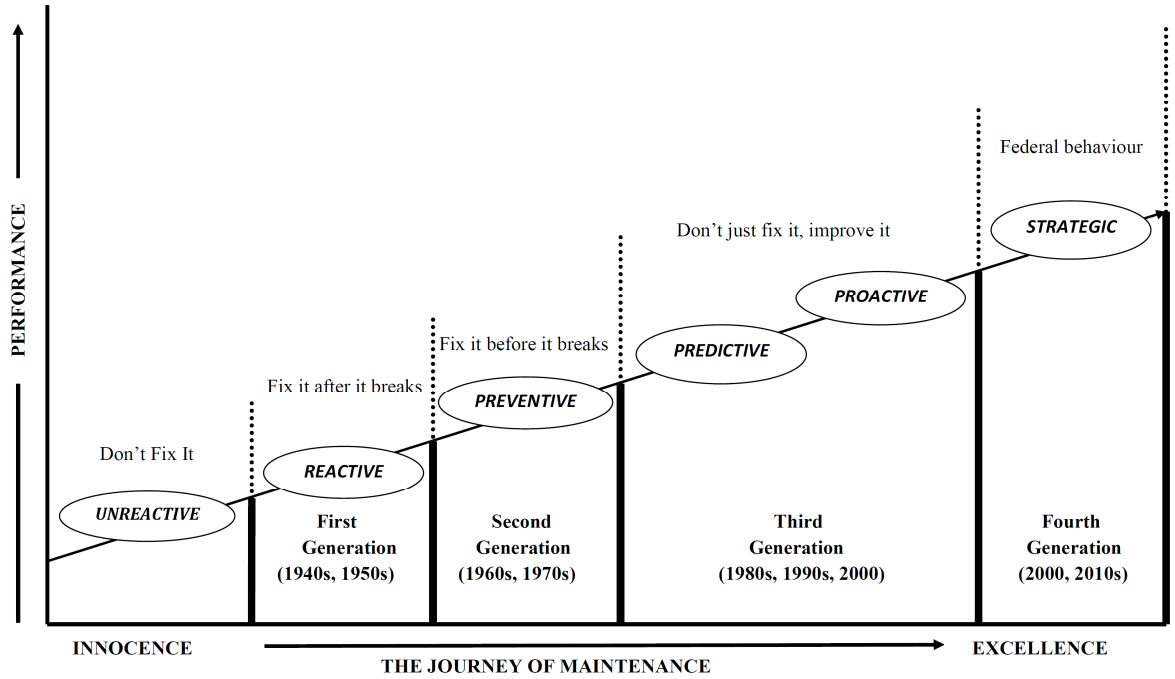

Figure1: Performance Journey of Maintenance Strategies

Run-To-Failure (RTF)

Mostafa (2004) defines RTF as the oldest type of maintenance and suitable for small, non-critical, low cost equipment (Ismail Mostafa, 2004).

Reactive Maintenance: it is a concept in which a highly skilled maintenance team is kept ready to step in whenever maintenance problem faced in production and the repairs are made by working overnights and on weekends (Dowlatshahi, 2008). However, the required spare and replacement parts held in heavy stock in anticipation of breakdowns. It is also undesirable strategy, now-a-days and almost no industry can adopt its principles.

Corrective Maintenance or Failure based Maintenance or Breakdown Maintenance

CM or FBM or BM is the maintenance or repair actions that executed after systems failure or upon occurrence of severe performance decline (Lin & Tseng, 2005). Furthermore, Mostafa (2004) interpreted as the unplanned activities undertaken to make the failed operating equipment into operating condition(Ismail Mostafa, 2004). Further, Iyer (1999) added it as unscheduled maintenance required as a result of failure to restore a system to acceptable performance level(Iyer, 1999). However, Bevilacqua and Braglia (2000) highlighted its main feature that actions are only performed when a machine breaks down (Bevilacqua & Braglia, 2000). There are no interventions until a failure has occurred

(Swanson, 2001). Furthermore, Soni (2013) called it restoration maintenance which meant "return equipment to its original condition so it can be maintained normally" while focus is on chronic minor breakdowns that collectively often total the highest amount of lost time(Soni, 2013). Wang *et al.* (2007) emphasise that such a firefighting mode of maintenance often causes serious damage of related facilities, personnel and environment (L. Wang, Chu, & Wu, 2007). Furthermore, Patidar (2016) enlist the disadvantage of CM or FBM or BM as unplanned stoppages, excessive damage, spare parts problems, high repair costs, excessive waiting and maintenance time and high trouble shooting problems (Wararkar). However, Mechefske and Wang (2003) studied & found that it is the original maintenance strategy appeared in industry (Mechefske & Wang, 2003).

Planned Maintenance

Maintenance actions based on preplanned basis can be termed as planned maintenance by (Ismail Mostafa, 2004), further classified as follows;

Scheduled Maintenance (SM)

Mostafa (2004) defined SM as periodic replacement of parts based on their age or service (Ismail Mostafa, 2004). However, in industries this has very close meaning to preventive maintenance as discussed below.

Preventive Maintenance (PM)

Iyer (1999) defined PM as the scheduled maintenance required in order to operate a system at an acceptable level of performance(Iyer, 1999). However, PM encompasses all planned, scheduled and corrective actions before the equipment fails(Ismail Mostafa, 2004). Furthermore, Wang (2002) precisely featured as the maintenance that is performed before systems failure in order to retain equipment in specified condition by providing systematic inspections, detection, and prevention of incipient failure(H. Wang, 2002). Wang *et al.* (2007) classified PM in three categories i.e. time-based preventive maintenance (TBM), condition-based maintenance (CBM), and predictive maintenance (PdM) (L. Wang et al., 2007). However, in the TBM the word ''time' may refer to calendar time, operating time or age of part and this is decided as per the reliability characteristics of equipment to plan & perform maintenance periodically to reduce frequent and sudden failure. Number of industries worldwide seek and adopt effective and efficient maintenance function (Predictive/ Pro-active) such as CBM, RCM and TPM over the traditional firefighting reactive maintenance approaches(R. K. Sharma, Kumar, & Kumar, 2005).

According to Kumar U. *et al.* (2013), the extended balanced scorecard (BSC) and the multi-criteria and multi-hierarchical frameworks are effective tools for evaluating and measuring the performance of condition-based maintenance and predictive maintenance; the BETUS tool is useful for e-maintenance and remote maintenance performance evaluation(U. Kumar et al., 2013). However, the list of indicators or most popular set is a scorecard which frequently used to group maintenance KPIs and show different faces of the maintenance function(Tsang, 1998). In addition, BETUS, is a tool mainly developed to support predictive and proactive maintenance needs in the form of performance measurement and it uses various corporate IT systems as data input(Kans, 2008). Predictive maintenance approach is monitor the health of the equipment and sense the generation of a defect well in advance in running equipment so that preventive action is taken timely to avoid any surprise or unforeseen failure of the equipment(Patidar & Rao, 2012).

In the 1970s, a more synergistic approach to maintenance function linking to reliability (R) and maintainability (M) was recognized. The term "R & M" became very popular, which gave birth to RCM. RCM is basically a management

methodology that is being utilized more often, chiefly in equipment intensive industries. Recently, it has been successfully applied in power distribution systems (Dehghanian, Fotuhi-Firuzabad, Aminifar, & Billinton, 2013), railway networks (Macchi, Garetti, Centrone, Fumagalli, & Pavirani, 2012) and steel companies(Deshpande & Modak, 2002). Furthermore, RCM is a way of capturing the potential causes of downtime and poor performance by preventing failures and having a proactive approach to operations and maintenance(Igba, Alemzadeh, Anyanwu-Ebo, Gibbons, & Friis, 2013). Selvik and Aven (2011) suggests an extension of the RCM to reliability and risk centered maintenance (RRCM) by also considering risk as the reference for the analysis in addition to reliability(Selvik & Aven, 2011). One of the shortcomings of RRCM framework is difficult to trace out the limited assessments of risk and uncertainties. Further, it does not fit for SMEs. Moreover, RCM is time consuming and applying a full-blown RCM methodology requires management commitment and organizational openness(Vatn, Hokstad, & Bodsberg, 1996). The RCM model objective (improved reliability and cost savings) is only suitable to those manufacturers who design, operate and maintain their own products(Igba et al., 2013). In addition, RCM requires large amounts of data to be effective, while the data showed that SMEs management suffer from a lack of historical equipment data.

According to Nakajima (1988) (Nakajima, 1988) vice-chairman of Japan Institute of Plant Maintenance, TPM is a combination of American preventive maintenance and Japanese concepts of total quality management and total employee involvement. Further, Total Productive Maintenance (TPM) as the name suggests consists of three words: Total: signifies to consider every aspect and involving everybody from top to bottom; Productive: emphasis on trying to do it while production goes on and minimize troubles for production; and Maintenance: means equipment upkeep autonomously by production operators in good condition – repair, clean, grease, and accept to spend necessary time on it (Ahuja & Khamba, 2007). Kumar *et al.* (2014) Portraits TPM as a relatively new but very effective process that led to better maintenance and upkeep of the equipments and resulted in enhanced reliability of equipments and quality of products (J. Kumar, Kumar Soni, & Agnihotri, 2014). Furthermore, TPM is an innovative approach to plant maintenance that is complementary with TQM, VSM, JIT, TEI, Continuous Performance Improvement (CPI), and other world-class strategies (Cua, McKone-Sweet, & Schroeder, 2006). TPM tools play a strategic role not only in directly gaining better performance but also in preparing the right environment for efficient adoption of JIT and TQM techniques (McKone, Schroeder, & Cua, 2001).

INTEGRATION OF MAINTENANCE STRATEGY

To achieve high strategic goal, selection of single maintenance strategy for plant asset is not enough. Therefore, integration of maintenance strategies becomes more fruitful for achieving desired result. Based on the above review studies on maintenance function and manufacturing performance, a conceptual model has been proposed to understand the relationship as presented in figure 2.

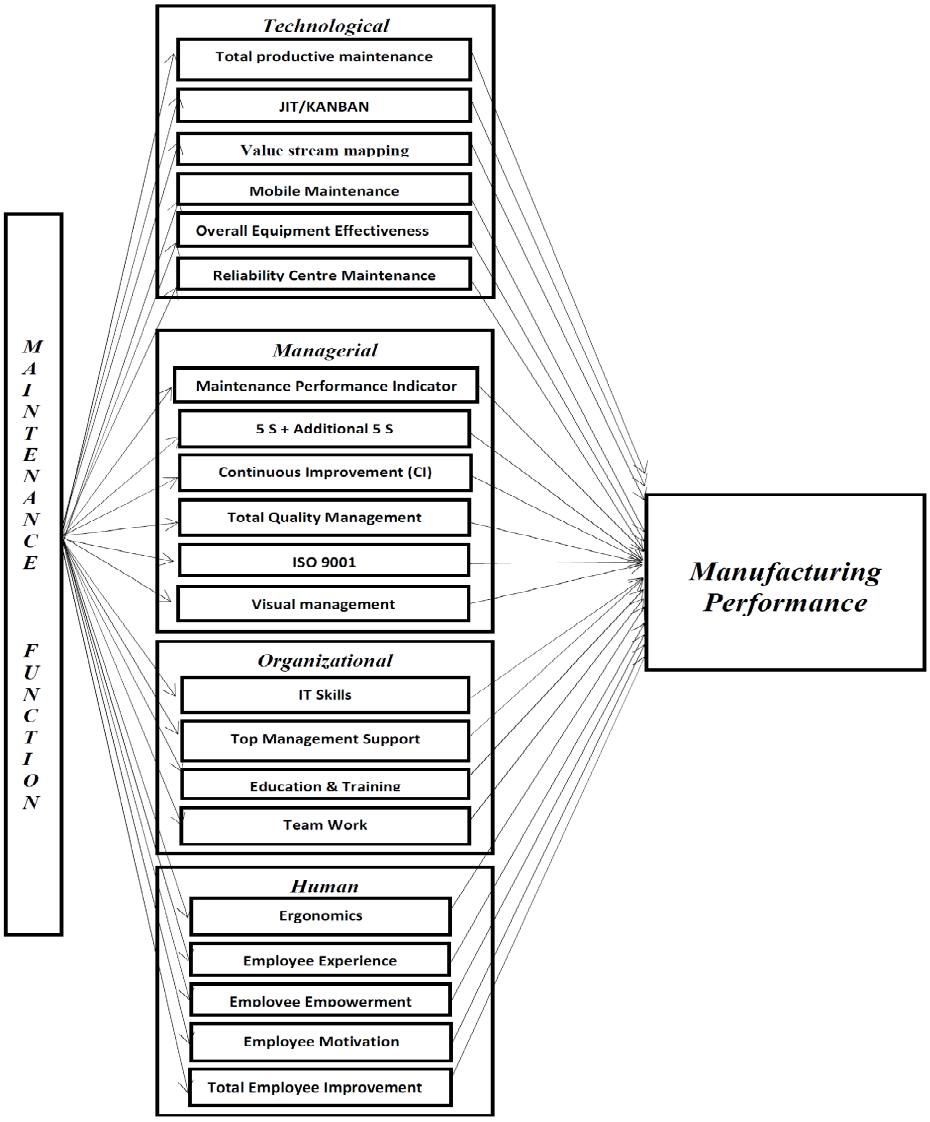

Figure 2: Integrated Maintenance Model

Figure 2 shows the hypothetical maintenance model which interlinks maintenance function to manufacturing performance. In this maintenance model some factors like technological, managerial, organizational and human related factor play mediator role between maintenance function and manufacturing performance. However, integrated maintenance model may require as per the need particular industries. Through this model many hypotheses may be generated like "technological factor-value stream mapping" generated mainly three hypotheses given as below:

H1: The maintenance function has a direct, positive effect and leads to better manufacturing performance.

H2: Maintenance function is positively correlated with value stream mapping (VSM).

H3: VSM is positively correlated with manufacturing performance.

Authors' offers number of such hypotheses to show the relationship between maintenance function and manufacturing performance which latterly examine by structural equation modelling (SEM) techniques

CONCLUSIONS

- This study provides a detail classification of maintenance strategies based on previous research. Maintenance strategies classification reveals the journey of maintenance function toward excellence. Vast literature on maintenance strategies and its growing adaptation in industries indicate the interest of researchers and practitioners.
- A hypothetical integrated maintenance model suggest for managers as per the current need of industries. This integrated maintenance model offer future research for academician as well as industry personnel. From the literature reviews, it can be seen that maintenance is a very effective strategies for management as well as manufacturing organizations.
- The practical approaches of different organizations are different so the modification in them may be accordingly. It is expected that this study will serve as a seed for researcher and practitioners. There is a huge need for research in the field of the integrated maintenance concept which best fit in industries perimeter.

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